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Seals Flow Code Development–93

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Proceedings of a workshop
held at the NASA Lewis Research Center
Cleveland, Ohio
November 3–4, 1993

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National Aeronautics and
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Preface

Seals Workshop of 1993 continues to provide a forum for information exchange. The program overview presents a series of charts depicting seal configurations studied in 1993 and goals proposed for the out years while calling attention to those requesting information on the use of codes (refs. 1, 2). Codes released include:

SPIRALI - A computer code to calculate leakage and dynamics of incompressible, turbulent, plain and spiral grooved cylindrical and face seal configurations.

IFACE - A computer code to calculate leakage and dynamics of incompressible , isoviscous, face seal configurations with pockets, steps , tapers, turbulence, and cavitation.

GFACE - A computer code to calculate leakage and dynamics of laminar gas lubricated face seals with a variety of "lift pad" configurations.

SCISEAL - A CFD code for analysis of leakage, fluid dynamics for research and design of a variety of seal configurations with a capacity of extension to other classes of problems. The current SCISEAL release is limited to annular, stepped, and tapered cylindrical seals with architecture in place to expand to other seals configurations as well as other classes of problems. The code includes colocated grids higher order schemes (3 in space, 2 in time), rotating and moving grids, and turbulent models.

A description of the GUI (graphical user interface) and the executive shell illustrating features of the code usage was presented. The GUI is very important to any modern code that is to be available to and used by the general seals community and not just by the code developers. Interfacing codes is a difficult task even when the codes are developed within the same organization and requires a very carefully developed GUI to facilitate generalized usage. The GUI represents just one portion of the seals code project development plan.

Sufficient workshop time was devoted to hands on usage of both the industrial (SPIRALI, IFACE, GFACE, others) and scientific code (SCISEAL).

The impact of environmental and customer driven seal requirements was introduced at the workshop providing an initial look at a very complex engineering-social-economic problem for the (generally) customer driven aerospace and legislative driven industrial seals companies and users. Most seal companies have "zero net leak" configurations but in many cases leakage is required for lubrication, cooling, or dynamic stability and presents a major conflict. Environmental considerations, simulation codes, manufacturing, regulation, barrier fluids, aerospace related sealing, and "what's comming" rounds out the presentation.

Some of the more controversial discussions followed the seal code users report where code comparisons to seal leakages were in reasonable agreement but the dynamic data coefficients were not. Codes comparison between CSEAL (Texas A&M University) and GCYL and HSEAL (Mitsubishi) and ICYL, provides an initial look with some industry feedback. EGG (Sealol) and SPIRALG codes are in good agreement with experimental leakage data but the dynamic coefficient predictions differ.

Comparisons of SPIRALG (a narrow groove laminar code) to turbulent wide groove/land data did not agree. The principal investigaters agreed to iterate the problem to a solution.

NASA Lewis' brush seals program development was discussed. The program includes flow visualization, characterization of flow patterns and quantization, bench testing, T-700 (and T-55) engine testing and materials studies (optical, SEM and XDS) of both bristles and rub runners. Seals that were placed in the turbine environment survived with severe wear (as was expected) and those specifically designed for a compressor discharge seal looked very good after 20 engine hours. A simplistic method that correlates much of the brush seal flow data

del p = a V + b V**2

is discussed. The coefficients are based on flows through porous media.

Cryogenic (fluid nitrogen and hydrogen) seal program at NASA Lewis Research Center tested 4 different rub runner materials with Hayners 25 bristles at surface speeds to 525 fps and 300 psi drop across a 5-seal configuration. Brush spacing and number of brushes alter the leakage with perhaps 0.001 inch grooving of the rub runner. The hot gas facility (NASA/ARMY/USAF) continues to test a variety of brush, labyrinth and advanced seal configurations. Test conditions include pressures to 150 psi, temperatures to 500 F (1200 F potential) at speeds to 30 000 rpm (670 fps). Selected tours were provided to both facilities.

The ceramic seals are being developed and manufactured under contract to Technetics and show significant promise. Several bristle materials (SiC, Al2O3, SiO2), brazing and manufacturing methods were investigated. SiC bristles with metallic side washers was selected for further development under a USAF contract.

Seal companies are working with government organizations to gain testing experience and life of brush seal configuration in a T-407 engine simulation test. The merits of replacing the balance piston labyrinth seals with brush seals was investigated with mixed results. Endurance testing (seal life) with rotor runout tends to be a major problem. Brush seal design revision and new proprietary seal characteristics require investigation.

Analytical/numerical/experimental work continues to provide insights and code validation data for brush seal flows and dynamics characteristics. Work is also continuing on analysis and definition of secondary flows, pocket flow, and thermohydrodynamics of simulated cylindrical and face (bearing/seal) geometries using liquid crystal and full field flow tracking (FFFT) techniques.

The USAF brush seal development program (IHPTET- PRDA II) goals were stated as surface speeds to 900 fps temperatures to 1200 F and pressure drops to 50 psi. The brush was to provide substantially lower leakage than the labyrinth at equivalent operating life. Under PRDA III, the goals increased speed to 1400 fps, temperature to 1400 F, and pressure drops to 150 psi/stage with the brush seal providing enhanced stability. To date, over 40 seals have been tested to maximum conditions of 1200 F, 1080 fps, 60 psid, and 0.0045 inch rotor runout with excursions to 0.019 inch. Test rigs for seals to 20 inches in diameter are available. Tribological pairing and bristle relief geometries have been integrated into the program and test data are presented.

Testing and code validation for pocket and plain bearing seal geometries at Techische Universitat Braunschweig were discussed.

The use and some results from a set of codes CSTEADY and CTRANS were presented by John Crane Inc. These codes deal with face seal analyses and consider the thermohydromechanical effects in face seals, materials, asperites, and seal geometries for optimization of design including balance ratio. The code appeared expedient, fast, with a convenient GUI.

A variety of face and brush seal testing at Allison Gas Turbines was presented for wide dam face seals. Sketches of seal geometry and performance data (leakage, torque, stiffness) were discussed for three basic geometries: 8-pad Rayleigh-Step; Tapered spiral groove (3 tapers); hydrostatic, inherently (no pocket) and orifice (with pocket) compensated. Test conditions included, temperatures to 1200 F, pressures to 665 psia; and surface speeds to approximately 1000 ft/sec with a leakage goal of 10 scfm. Spiral groove and Rayleigh step seal configurations are most promising.

The USAF secondary gas path seals and mainshaft air/oil seals program was presented. The IHPTET program and testing leads to F119 engine applications. Leakage and performance goals for military engines are double thrust/weight, decrease SFC by 40 percent, decrease secondary air flow leakage by 60 percent with a 50 percent increase in mainshaft speed. Seal rotordynamics and R and D programs are presented for brush seals. Generally brushes are more than 20 percent better than labyrinth seals in the long term. Mainshaft air/oil seals programs were also presented as well as future technology needs.

GM presented a new high speed test facility capable of testing a variety of bearing and seal configurations and essentially invited customer testing.

Hypersonic engine seal characteristics are delineated (materials and geometry), leakage models cited, and test results provided illustrating good agreement between data and theory at temperatures to 1350 C and pressures to over 40 psi with and without surface motion.

New dynamic test data for spiral groove (wide lands and grooves) and smooth annular seals with eccentric operation was presented. With increasing eccentricity (e) Kxx decreases, Kyx increases, Cxx increases; whirl frequency ratio (stability indicator (WFR)) at 16 000 rpm shows little dependence on eccentricity up to e = 0.5, the testing limit.

$$Keq = (KxxCyy + KyyCxx - CyxKxy - CxyKyx)/ (Cxx + Cyy)$$

$$WFR **2 = ((Keq-Kxx)(Keq-Kyy) - KxyKyx)/((CxxCyy - CxyCyx) omeg**2)$$

The pressure measurements of a three-wave journal bearing were presented and are in good agreement with theoretical predictions. The advantage of such a bearing is its stability and enchanced load carrying capacity.

To conclude the 1993 Workshop, future activites will move toward face, lip, and some proprietary seals as low leakage with supportive dynamics. The next Seals Flow Code Development Workshop is set for Spring 1995.

1. Liang, A.D. and Hendricks, R.C.: Seals Flow Code Development - 92 , NASA CP 10124, 1992.

2. Liang, A.D. : Designing Seals with the Experts. Machine Design, Feb. 1993, pp 32 37.

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INTRODUCTION/PROGRAM OVERVIEW

Anita Liang
NASA Lewis Research Center
Cleveland, Ohio

REPORT ON NASA CONTRACT NAS3-25644
"NUMERICAL/ANALYTICAL/EXPERIMENTAL STUDY OF FLUID DYNAMIC FORCES IN SEALS"

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EARTH-TO-ORBIT PROPULSION PROGRAM
OFFICE OF ADVANCED CONCEPTS AND TECHNOLOGY
NASA HEADQUARTERS

CONTRACT INITIATED IN 1990

CONTRACTOR: MECHANICAL TECHNOLOGY INCORPORATED (MTI)
LATHAM, NEW YORK

SUBCONTRACTOR: CFD RESEARCH CORPORATION (CFDRC)
HUNTSVILLE, ALABAMA

PROGRAM MANAGER: WILBUR SHAPIRO

PRINCIPAL INVESTIGATORS: BHARAT AGGARWAL, MTI
JED WALOWIT, INDEPENDENT
ANDRZEJ PRZEKWAS, CFDRC
MAHESH ATHAVALE, CFDRC

NASA TEAM MEMBERS

CONTRACTING OFFICER:	LINDA KENDRICK
CONTRACT MANAGER:	ANITA LIANG
TECHNICAL MANAGER:	BOB HENDRICKS
SEALS RESEARCH:	GENE ADDY MARGARET PROCTOR JIM WALKER
BEARINGS RESEARCH:	GENE ADDY FLORIN DIMOFTE JIM WALKER
SYSTEM ENGINEERING:	CHRIS FULTON

PEER REVIEW MEMBERS (PRESENT AT THE WORKSHOP)

PRIT BASU, EG&G SEALOL
DARA CHILDS, TEXAS A&M
CHUCK MERKLE, PENN STATE UNIVERSITY
JOHN MINER, PRATT & WHITNEY
JOHN MUNSON, ALLISON GAS TURBINE
JOE SCHARRER, ROTORDYNAMICS-SEAL RESEARCH
BILL VOORHEES, U.S. NAVY

PAST YEAR ACTIVITIES

CODE DISSEMINATION (PC VERSION)

MACHINE DESIGN ARTICLE

PEER REVIEW COMMENTS

CONTRACT MODIFICATIONS

RELEASE OF CONFERENCE PROCEEDINGS

CODE DISSEMINATION

Prithwish Basu - EG&G Sealol
Jack Braun - University of Akron
Berci Cherpician - Torrington Company
Dan Cornell - Westinghouse
David Elrod - Sverdrup/MSFC
Carl Grala - Navy
William Fohey - Williams International
Robert Hibbs - Rocketdyne
Ralph Gabriel - Durametallics
V. Kadambi - Textron Lycoming
Roger Ku - Conner Perpherals
Richard Jones - Stein Seal
Chester Lee - Solar Turbines
Victor O'Beid - Rotor Bearing Technology
Mark Makhobey - Car-Graph Inc.
John Miner - Pratt & Whitney
Bahram Movahed - Sundstrand
A. Parmar - John Crane
Eugene Ruddy - John Crane
Norman Samurin - Dresser Rand
Peter Withers - Rolls Royce

Barry Bixler - Rolls Royce
Shou-Hao Chen - Quantum Corp
Dara Childs - Texas A&M University
Ronald Dayton - Air Force
Robert Evenson - Revovle Technologies
Alston Gu - Allied Signal Aerospace
Wes Franklin - Bentley
George Hosang - Sundstrand Power System
Harold Greiner - EG&G Sealol
Meng Kann - Ingersoll Rand
Frank Kushner - Elliott Company
John Leary - The Trane Company
Simon Leefe - BHR Group Ltd
Mike O'Brien - Textron Lycoming
Ellen Mayhew - Air Force
Vijay Modi - Columbia University
John Munson - Allison Gas Turbine
John Radford - Kardon Ring and Seal
Richard Salant - George Inst. of Tech
John Waggott - Dressler Rand
Shifeng Wu - John Crane Seal

DESIGN SEALS WITH THE EXPERTS
MACHINE DESIGN
FEBRUARY 12, 1993

Fredric Aichele - NWD Technology

Paris Altidis - Powertrain Engineering

N.K. Bhardwaj - Solar Turbines

Berci Cherpician - Torrington Corp
(Received Codes)

Ralph Gabriel - Durametallic
(Received Codes)

Eric Hao - Dorr-Oliver

Frank Olsofka - Ingersoll-Rand

Shu Peng - Parker Seal
(Received Codes)

Frank Savel - TRW Valve Division
(Cooperative efforts)

Richard Van Slooten - Praxair, Inc.

Peter Allen - Martin Marietta

Peter Amos - Advanced Products

Shuo-Hao Chen - Quantum Corp
(Received Codes)

Dan Cornell - Westinghouse
(Received Codes)

William Giesler - Allied Signal

John Leary - Trane Company
(Received Codes)

Kermit Paul - Fuller Kovako Corp

Eugene Ruddy - John Crane
(Received Codes)

Elizabeth Seidman - U of Cincinnati
(Received Literature)

CONTRACT MODIFICATIONS

TWO YEAR STRETCH

PROGRAM SCOPE REVISION

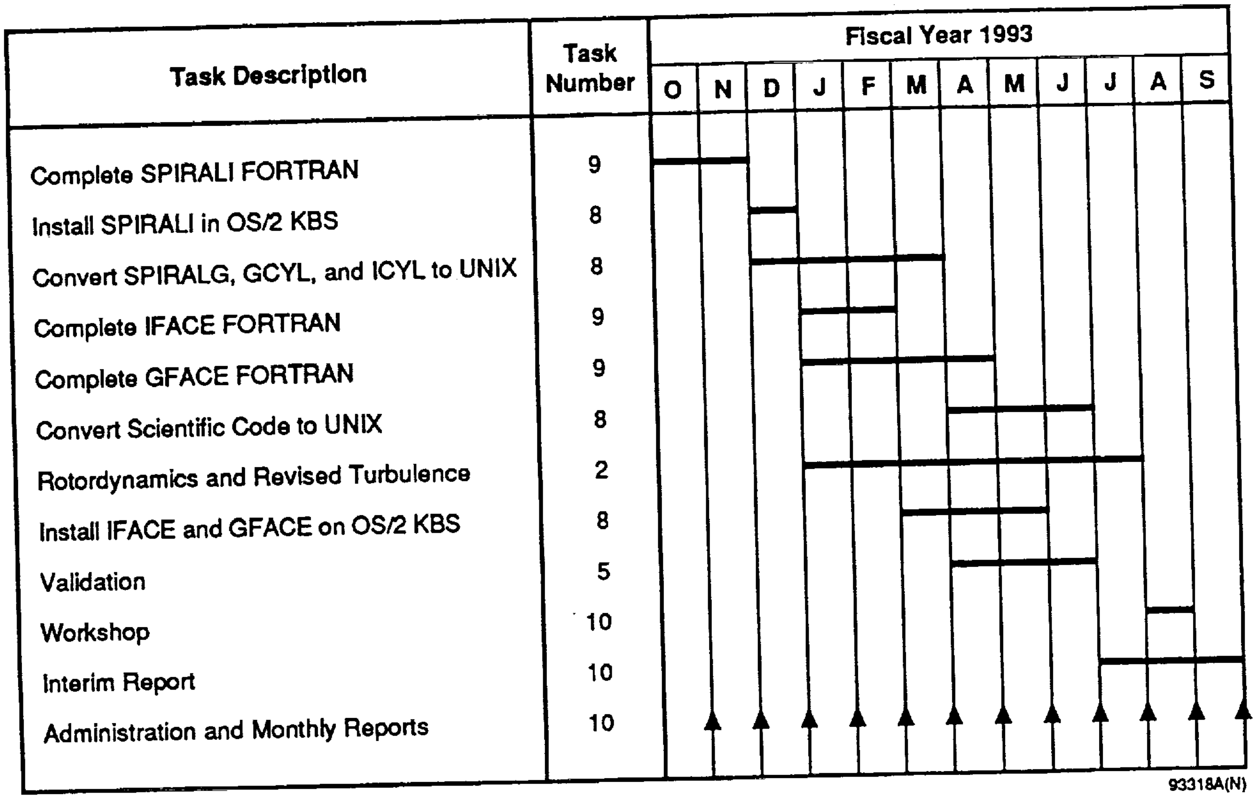

Figure 1. Fiscal Year 1993 Plans

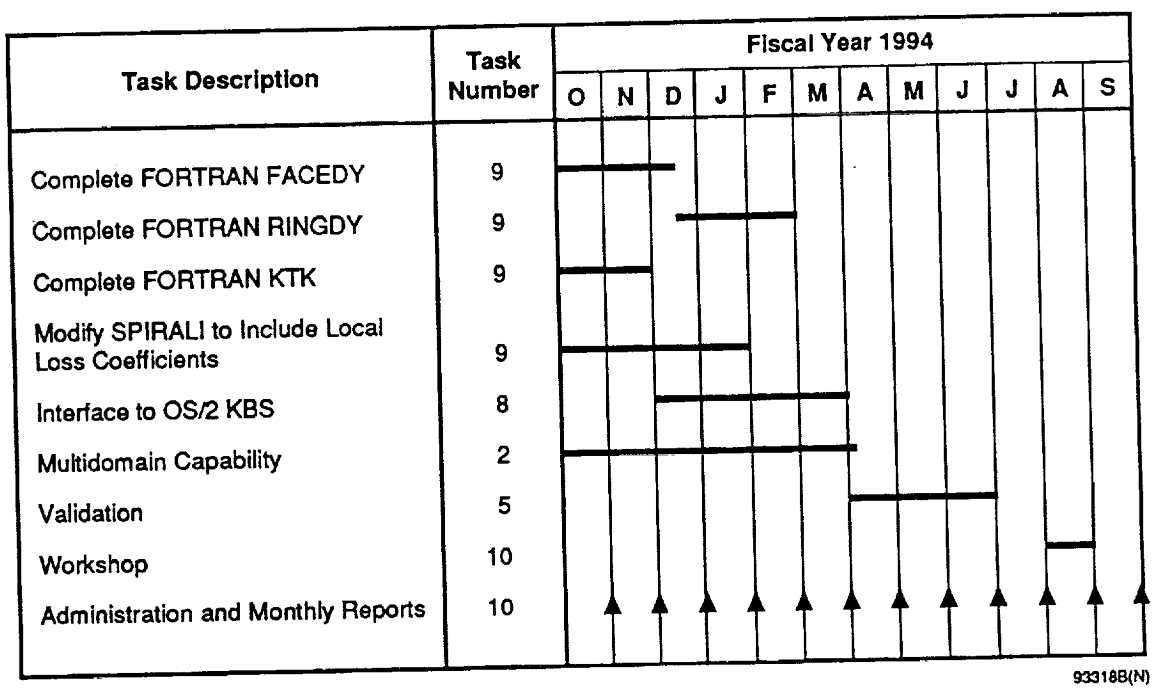

Figure 2. Fiscal Year 1994 Plans

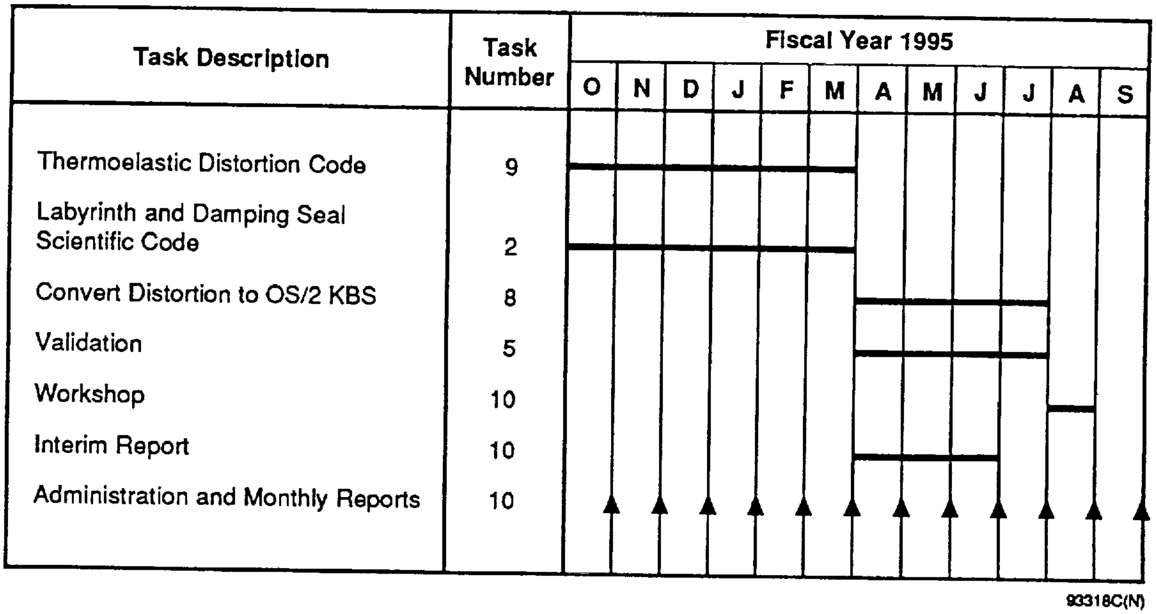

Figure 3. Fiscal Year 1995 Plans

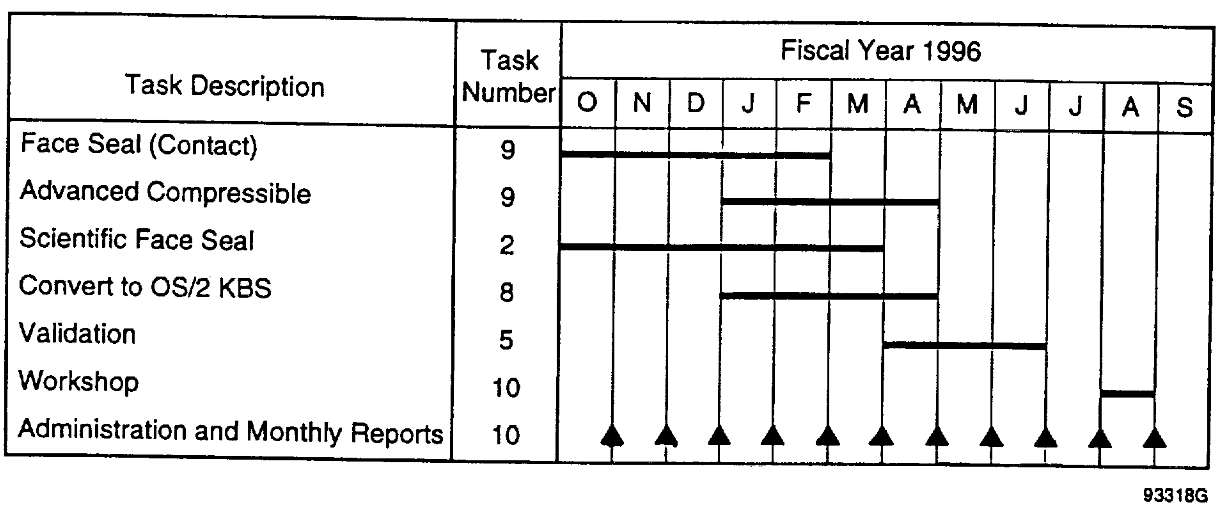

Figure 4. Fiscal Year 1996 Plans

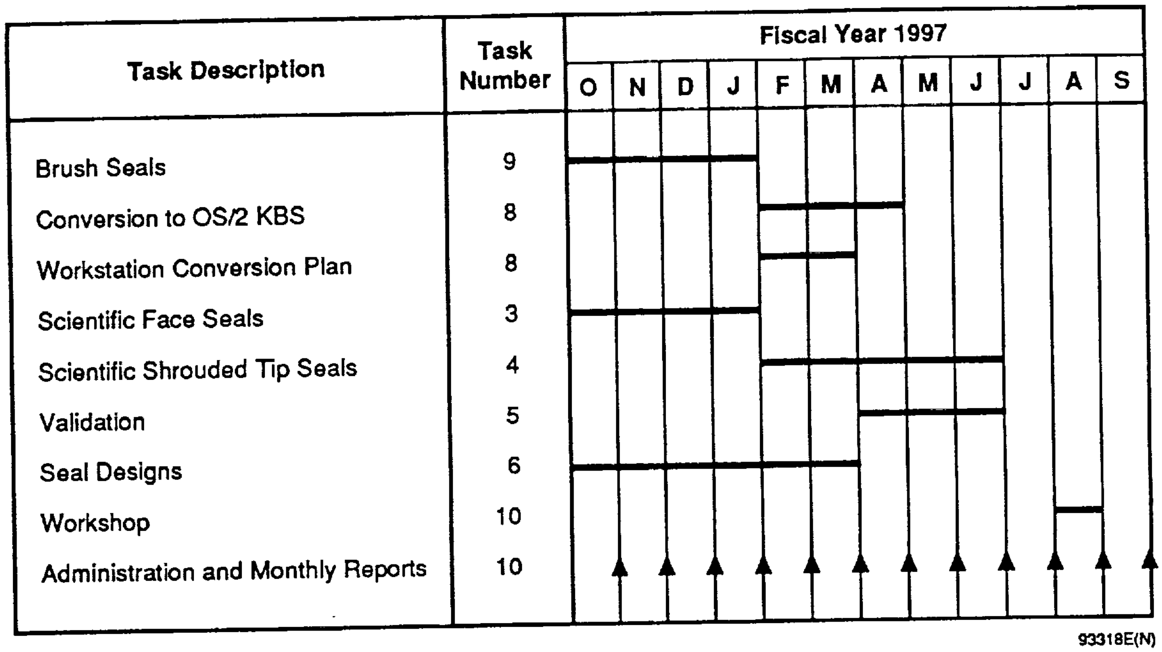

Figure 5. Fiscal Year 1997 Plans

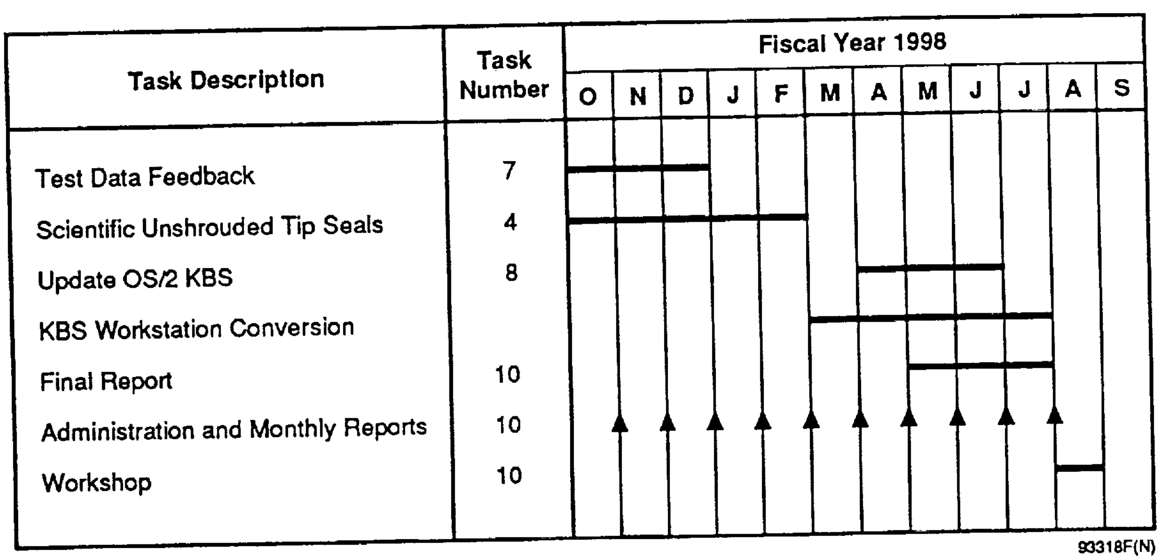

Figure 6. Fiscal Year 1998 Plans